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MARINE FISHES OF PANAMA AS RELATED TO THE CANAL

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ABSTRACT Recent papers by Eskinazi, compared to studies made on the Texas and Louisiana coasts 35 to 45 years ago and on the south Atlantic coast 15 years ago, show remarkable similarities of the estuarine fishes of northeastern Brazil and the northern Gulf of Mexico. Forty-five of 48 families of the two areas are in common and about 35% of the species are in common. On the west coast even greater correspondence might be expected between fishes of Peru and southern California, were it not for the restriction of tropical fishes by the Humboldt and California currents.

When the lithospheric plate under North America pulled away from Pangaea, strong swimmers and pelagic fishes maintained connections. Thus, the marine fishes have had strong connections for the last 70 million years. Further, the Pacific and Atlantic faunas were connected until the mid-Pliocene when Isthmus America became continuous about 5.7 million years ago.

Marine euryhaline fishes are much more abundant than their freshwater counterparts. Thus large numbers of marine fishes are found in the fresh waters of Panama. One hundred thirty-seven (137) marine fishes have been found there and 57 species have taken up more or less permanent residence. No freshwater fish have taken up residence in the seas of Panama. The freshwater fishes of Central America came from the south and their movement has been very slow. Isthmus America was a ridged mountainous area with short, small rivers and small basins. The estuaries were small or nonexistent. Thus, one avenue for spread of fishes from fresh water was generally nonexistent. There are 32 river basins in Panama and fish have little access from one to the other. So the river basins have an insular aspect. The Canal runs through only three river basins. There are generally no problems to the passage of freshwater fishes in the Canal but they are stopped by even low salinity and, if back pumping becomes necessary to maintain the lakes used in the operation of the locks, most freshwater fishes will not traverse the Canal. Thus, it may be said that there is little chance of transfer of freshwater fishes from one coast to the other. However, the tarpon has already crossed the isthmus and eight other species, including blennies, gobies and pipefishes, have made the passage according to ichthyological collectors. Actually only four fishes are indubitable crossers. Back pumping will increase the potentiality a great deal but no foreign process of gene flow or heredity other than what is present all over the world today and which was present when the Pacific and Atlantic were connected, is to be expected. Thus a sea level canal would present a new situation but nothing that could be antibiological or deadly.

COMMINGLING OF FISHES BETWEEN NORTH AND SOUTH AMERICA

The zoogeography of marine and freshwater fishes are quite different affairs, and nowhere is this shown more clearly than in a comparison of the coastal fishes populations of northern South America and southern North America with parallel comparisons of the freshwater fishes of the same regions. The question is touched upon here because it relates to the composition of the fishes of Panama.

MARINE FISHES

Data concerning the coastal ichthyological fauna of northeastern Brazil which were recently presented by Eskinazi (1972, 1974) show the remarkable resemblance between the genera and species of coastal fishes of northeastern Brazil and the coasts of Louisiana and Texas as described by Gunter (1938a, 1938b, 1941, 1945). The northern Gulf of Mexico lies in the so-called Carolinian Biogeographic Province which also includes the Carolinas, Georgia and northern Florida on the Atlantic. The similarity of the shallow-water fish fauna of the Atlantic and Gulf coasts of this province is now well known. Possibly the best listing of the Atlantic ichthyofauna of this region for comparative purposes is that of Anderson and Gehringer (1965), although it concerns the Cape Canaveral area which is at about the southern border of the Carolinian.

A thorough comparison of shallow-water marine fishes of North and South America would be worthwhile, but that subject is not the concern of this paper. However, a cursory comparison of the species listed by Eskinazi (1974) for northeastern Brazil shows that about 35% of the species along those shores are the same as those off the northern Gulf coast of the United States. Similarly, genera coincide closely and, with regard to Brazilian families, only the Cichlidae, the Erythrinidae and Symbranchidae, freshwater families which are sometimes taken in low-salinity coastal waters of Brazil, are excluded from the northern Gulf. The latter two come to southern Mexico and one comes to Florida and one cichlid has reached Texas fresh waters. Thus 45 of 48 families of the two areas are in common. The strong similarity between the shallow-water marine fishes of the North American east coast, south of Cape Hatteras, and northeastern Brazil is impressive and it may be said that strong ichthyofaunal connections extend from subtropic zone to subtropic zone, inclusively.

On the western coasts of the Americas an even greater correspondence of the marine, shallow-water ichthyofauna from southern California to Peru might be expected because of more equable (low) water temperatures and (high) salinities and a generally more similar environment as a

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whole, with rocky shores, few estuaries and a narrow shelf. However, Rosenblatt (1967) points out the restriction of the tropics by the Humboldt and California currents on the west coast of the hemisphere.

The geographic reasons for the relations of the coastal fishes of the Americas is worth a short examination. The lithospheric plate under the North American continent began to pull away from the great land mass of Earth before South America did (Raven and Axelrod 1975) and the two continents were well apart (approximately 3,000 kilometers) during most of the Cretaceous Era, for about 100 million years beginning about 150 million years ago. During that period pelagic fishes and strong swimmers maintained connections over the area.

Later, near the end of the Cretaceous Era (cf. Dengo 1973), a series of volcanic and nonvolcanic islands arose which connected the two continents along lines of the future isthmus. This came about some 70 million years ago. Then the shore species of fishes, well separated and differentiated over some 80 million years or so, including the weakly motile bottom-dwellers, spread between the two continents by rafting and the other accidents of biological spreading, which become significant over long periods of time. "Rafting" by fishes would consist of floating along underneath, hiding in crevices or even clinging beneath the "raft" and as such would seem to be more common and successful than for air-breathers.

Thus it may be said that the estuarine fishes of North and South America have had fairly strong connections for approximately 70 million years and possibly more. Furthermore the Pacific and Atlantic faunas of both continents were not separated until the mid-Pliocene when Isthmus America began as an unbroken connection between the two continents (Emiliani et al. 1972). That was about 5.7 million years ago.

Marine fishes of Panama are a section of a vast inshore fauna which extends from subtropic across to subtropic on either side of the equator and on both the Atlantic and Pacific coasts. It is composed of several hundred species, a few of which are no doubt still unknown. These were generally treated by Meek and Hildebrand (1923–28), who listed 757 species. Details of the history of the study of the fishes of Panama have been given by Loftin (1965).

Actually, the chief interest here is in the euryhaline marine fishes, those which are capable of withstanding fresh water. There are not a great many euryhaline species in the strict terms defined by Gunter (1942, 1956), but there are a great many species which tolerate some admixture of fresh water and sea water. Gunter defined a fully euryhaline species of fish as one which has been recorded in both pure fresh water and pure sea water by competent observers. In comparison the partially euryhaline fishes which tolerate mixtures of fresh water and sea water enter from both fresh water and the ocean. However, Gunter pointed out that the marine invaders are much more numerous. In fact the estuarine fauna is predominantly of marine origin all over the whole world.

Miller (1966) lists 137 species of marine fishes which are to be found in the fresh waters or almost fresh waters of Panama, and he states that in the whole of Isthmus America approximately 57 species, or one-third of the marine invaders, have taken up more or less permanent residence in fresh water.

With regard to "pure fresh water," all water from land and even rain water contains some mineral salts. The only boundary between sea water and fresh water which is objective and chemically determinable, is at the concentration where the ratio of the chloride ion to the other ions changes from that of sea water to that of fresh water (Price and Gunter 1964). On coasts with drainage over silicate rocks and sediments the water is "soft" and the ratio change takes place at near 0.18‰. On coasts where the drainage is over carbonate rocks and the fresh water is "hard" the salinity at the change point to fresh water may be near 0.6‰ saline or higher than oligohaline sea water* of other areas.

FRESHWATER FISHES

No freshwater fishes have taken up residence in the seas of Panama so far as the records show, and as the obverse side of the coin there is a group of freshwater fishes over the world which are extremely reluctant to enter salt water and are never found there (Myers 1938). Myers called them Primary freshwater fishes. A second group, which is made up of those species that occasionally are found in low-salinity waters and sometimes even higher, he called Secondary freshwater fishes. A third group, which may traverse the whole salinity gradient for various reasons, are called Peripheral freshwater fishes. They were originally named by Nichols (1928) who recognized that most of them were of marine affinity. These terms have been adopted by recent students of ichthyogeography (cf. Loftin 1965; Miller 1966).

Isthmus America, as a mid-Pliocene uplift, ranged from Tehuantepec, Mexico, to and including the coastal plain of Colombia, so that the southern part formed a little cap of northern South America. After this connection took place the freshwater fishes and other animals from both continents began to move up and down the isthmus. Older zoogeographers held that most fauna moved from north to south, but as Myers (1938) pointed out, "There is not a scrap of factual evidence . . . on which to postulate a North American origin of the present South American fresh water fishes."

Myers (1938) goes on to say that one characin and one cichlid of the South American fishes have reached Texas. Of the six families of common North American fishes, the

*Some purists would use "salt water" only for artificial brine mixtures and reserve "sea water" only for the oceans. However, there are too many "Old Salts" who have used "salt water" for sea water, or even for the sea itself, for such a change to come now.

four main ones (perches, darters, sunfishes and minnows) have not penetrated Isthmus America and only two suckers and one North American catfish are found below Tehuantepec. The Poeciliidae may be autochthonous to Isthmus America and specifically to the Yucatan land mass (Myers 1938; Miller 1966).

The freshwater fishes of Panama were first extensively studied by Meek and Hildebrand (1916). They listed 94 species of Primary and Secondary freshwater fishes and marine recent invaders. Meek and Hildebrand (1916, p. 233) stated that "the fish fauna of Panama is essentially that of South America and most of the forms seem to have entered from that direction."

Myers (1938, p. 343) has pointed out that "throughout the world the migrations of fresh-water fishes over extensive continental areas have been excessively slower than those of almost any creature that can creep, crawl, walk or fly, however closely that creature may have been bound by its ecological tolerance." And he stated that this is nowhere better illustrated than in Isthmus America.

If the ancestors of the characin and cichlid fishes now found in Texas and New Mexico left South America soon after the isthmus formed, they traveled at a rate of 1 mile in 475 years, 11.10 feet in a year or 0.365 inch (0.9266 cm) per day. This assumes a distance of 3,000 miles and a time span of 5.7 million years. Even if they started only a million years ago the speed of travel has been quite slow.

The reasons for this slow spread of the freshwater fishes are obvious. Isthmus America is mostly a ridged, mountainous strip of land with steep profiles and mostly short, small rivers. The river basins are small. In turn the estuaries are small and virtually nonexistent, especially in the dry season. Bealer (1947) made the statement that in Panama, 475 streams empty directly into the oceans. For that reason the abundant characins and neotropical catfishes in Panama, "a vanguard from the south of the great Amazonian fauna," (Miller 1966) cannot work their way along the sea shores. Even most Secondary fishes are precluded by full sea water and euryhaline groups, such as the Cyprinodontes, are shelter seekers and they do not roam the open beaches far from river mouths and estuaries. Gunter (1945) found only three on the sea beach among 9,010 specimens of six euryhaline species of cyprinodontoids in Texas waters, and these were near the passes to inside waters. Simpson and Gunter (1956), in a study of Texas coastal cyprinodontoids, set up no stations on the open sea beach because experience had shown that it was no place to catch these fishes. Gunter (1957) reported one *Cyprinodon variegatus* and 12 *Fundulus similis* on open beaches among 10,633 other fishes. A few yards away at nearby stations in the passes 584 of the two species were caught.

The numerous small river basins of Panama are well separated by steep ridges. There are 32 of these. In general the gradient is steep and the rivers are short. The Rio Bayano, the largest, is less than 100 miles in extent and many rivers are less than 10 miles long. The average length seems to be about 30 miles. During the dry season many of the smaller streams almost go dry, while in the rainy season they become torrents, and rises in height of 20 feet in an hour's time sometimes take place. These accounts are taken from Meek and Hildebrand (1916) and Loftin (1965), who have been chief ichthyological explorers.

According to Loftin (1965, p. 8), "Panama's system of drainages may be summed up as follows: a large number of short, steep isolated streams with small watersheds, which course rather directly down from the mountains to empty separately into the sea. This feature may be the single most important limiting factor in the dispersal of freshwater fishes in Panama."

The 32 basins in the 29,000-square-mile area average about 906 square miles in extent. The dividing spine generally runs closest to the Atlantic, except near the Canal, and the Chagres River Basin of the Atlantic side is the largest, but one of the lowest in average altitude. Half of the area of the country is above 1,000 feet in altitude with some peaks of 11,000 feet.

These basins are almost as isolated as so many tropical islands at sea, and they have both a higher percentage of marine fishes in their streams and a rather sparse fauna withal. The Panamanian river basins have an insular aspect.

The Canal connects or runs through only three river basins, the Chagres on the Atlantic and the two small basins between the Rio La Capira and Rio Bayano on the Pacific. Only the Chagres connects with the Canal and fish going from one basin to the other would have to go by way of the oceans, which is highly improbable, due to the reluctance of Primary fishes to enter even oligohaline salt water. In any case, no such instance has been noted. Even so, such a case would have probably caused less disturbance than the introduction of the Peacock *Cichlasoma* from Colombia into Gatún Lake did. The lake fishes have not been studied per se, but they are remnants of the riverine ichthyofauna of the Chagres River reported by Meek and Hildebrand (1916) and corroborated by Loftin (1965), species by species. Insofar as there were no natural lakes in all of Panama until the Canal was dug, it would seem that these fishes have been under some stress in the lacustrine environment. The Peacock cichlid is a predator on the other fishes and is now bringing other pressures. It grows to a large size, 20 to 30 pounds, takes the hook avidly one-by-one from a school and is a fine food fish. However, these attributes to not arouse great enthusiasm among Latin Americans.

In any case, it maybe assumed that there will be no passageway problems with freshwater fishes. Hildebrand (1939) said the freshwater fishes seemed to avoid the Canal, but, so far as his data went, this applied to the locks themselves and not the cut or the channel through the lake. This means that these fishes avoid salt water even in its dilute concentrations.

THE PANAMA CANAL AS RELATED TO FISHES

The Canal runs from Limón Bay on the Caribbean Sea at Cristobal on the northern side to Balboa on Panama Bay of the Pacific Ocean. The course is almost due south for 6.5 miles to Gatún Lock which lifts ships 85 feet up in three stages to Gatún Lake. This lake was formed by damming the Chagres River and covers 164 square miles with depths up to 85 feet. The southward course of the channel continues on in the lake for another 5 miles and then goes directly east. From that point on, there are over 600 cumulative degrees of turns before it reaches the southern terminal of the Bay of Panama, but all are generally southeast. From Gatún, the channel goes through Gaillard Cut to Pedro Miguel Lock, which lowers the ships 31 feet to Miraflores Lake. One mile farther on are the Miraflores Locks, which lower ships 54 feet back to sea level.

The Canal channel is 50 miles long from ocean to ocean. The isthmus is 40.27 miles wide at this point. There are six pairs of locks all 1,000 feet long and 110 feet wide, with walls of 81 and 82 feet high. It takes 7 hours for a ship to pass through.

A ship coming through from the north travels through salt water from Limón Bay to the lock at Gatún Lake where it is raised into fresh water. From there through Gatún Lake, Gaillard Cut and the Pedro Miguel Locks, the ship is in fresh water. In Miraflores Lake, the water is lightly brackish from the Miraflores Locks when the traffic is heavy. In summary, a ship or fish following the same path would travel through 6 or 7 miles of sea and brackish water to Gatún Lake, 37 miles of fresh water through the lake, 2 miles of slightly brackish water in Miraflores Lake and 4 miles of brackish water to sea water at Balboa.

There is no physical barrier to the crossing of the isthmus by a fish, as Hildebrand (1937) has stated. In this connection one should refer to Corps of Engineers reports (1956) and Hall (1956) concerning the locking of mullet (*Mugil cephalus*) from the St. Lucie Canal into the St. Lucie River when they were coming out of Lake Okeechobee, Florida. The Corps of Engineers found that it was much simpler to do this than to let the fish stack up and finally die in large masses at the locks while waiting to get back to sea.

Hildebrand (1939) presented a table from data collected over an unknown number of years by Panama Canal officials, which shows that the salinities at the "Inner Harbor" at both ends of the Canal ranged from 16.0 to 20.0 ‰ saline. In Miraflores Lake it was 0.1 to 3.0‰ and in Gatún Lake it was 0.005 to 0.02‰ (5 to 20 parts per million) or very soft fresh water.

Menzies (1968) towed animals through the Canal and reported a salinity of 25.5‰ in one of the Miraflores Locks, 1.0 in Miraflores Lake, 0.0 in Pedro Miguel Lock and Gatún Lake and 23.5 in one Gatún Lock. Neither time, place, method of salinity determination or depth was given by Menzies.

Abele (1972) found the salinity from top to bottom of the Pedro Miguel Locks to be 0.0 to 0.4‰, with an accuracy of 0.5‰.

Jones and Dawson (1973) took salinities and temperatures at 2-meter intervals from top to bottom at 19 to 22 stations from the Bay of Panama to Limón Bay April 13–May 1, and November 6–15, 1972, at the end of the dry and wet seasons, respectively.

Those authors found that in the locks the water was very homogenous from top to bottom. At the end of the dry season the salinities were near 30.0‰ in the lower Miraflores Locks, 4.0 to 6.0 in the upper and 1.0 to fresh from Miraflores Lake to Middle Gatún Lock. In the lowest lock, Gatún Lock, the highest salinity was 15.0‰. At the end of the dry season Miraflores Lake and the Middle Gatún Lock were salty, while the intervening areas were fresh.

Essentially these reports all agree that from Pedro Miguel Lock to upper Gatún Lock, inclusive, the water is fresh even in the dry season.

THE CANAL AS A PASSAGEWAY FOR FISHES

Hildebrand (1937) showed that the euryhaline tarpon *Megalops atlanticus* (Valenciennes) had crossed the Canal to the Pacific and they are still reported there from time to time, but ichthyologists fail to catch them in their infinitely miniscule collections and doubt that they have established breeding populations there (Bayer et al. 1970; McCosker and Dawson 1975). In fact it would be quite unexpected for this warm-water, estuarine-loving species to expand quickly along the shores of Pacific America. Recent sports fishing reports with pictures show the fish to be now 150 miles from Balboa.

In addition to the tarpon, McCosker and Dawson (1975) list the following fishes as having crossed the isthmus by way of the Canal:

Atlantic to the Pacific

Oostethus lineatus (Valenciennes). This is a completely euryhaline pipefish and breeds in both fresh and salt water as does *Syngnathus scovelli* on the United States Gulf coast (Whatley 1962).

Lophogobius cyprinoides (Pallas). This fish has been found in the Third Lock Lake but a significant meristic difference between this and the Atlantic populations has been reported. However, there is no proof that it has reached the Pacific.

Barbulifer ceuthoecus (Jordan and Gilbert). This species was collected in Panama Bay but it is said to not be euryhaline and may have "crossed" in water ballast.

Lupinoblennius dispar Herre. Found only in Miraflores Lock, not in the Pacific.

Hypleurochilus aequipinnis (Günther). A breeding population was found in Miraflores Lock, but is was not taken in the Pacific.

Pacific to Atlantic

Gnathonodon speciosus (Forsskål). This fish has been taken from the lower Gatún Lock but has never been seen in the Atlantic.

Ombranchus punctatus (Valenciennes). This Indo-Pacific goby has been found in Limón Bay. It is also found in Trinidad and Venezuela. Possibly it has been there for ages.

Gobiosoma nudum (Meek and Hildebrand). This goby was reported from Galeta Reef (Atlantic) one time.

Of the eight above species listed by McCosker and Dawson (1975) under the headings, "Marine Fish Migrants, Atlantic to Pacific," and "Pacific to Atlantic," there is one large fish, a carangid; one pipefish; three blennies and three gobies. Of these the pipefish *Oostethus lineatus* and the gobies *Ombranchus punctatus, Gobiosoma nudum* and *Barbulifer ceuthoecus*, have been found in the other ocean. The pipefish seems to be an authentic migrant to the Pacific. The goby *Ombranchus punctatus* could have scarcely spread from Limón Bay to Trinidad and Venezuela since the Canal was opened and the most reasonable conclusion is that it has been a resident of both coasts for a long time. The goby *Barbulifer ceuthoecus* is admittedly stenohaline and came in ballast. *Gobiosoma nudum* seems to be an actual migrant across the isthmus. Thus the tarpon, the pipefish and one goby are indubitable migrants across the isthmus by way of the Canal. At this rate it will take the 66 euryhaline fishes of Panama waters, according to Miller's (1966) count, a matter of 1,950 years to cross the Canal as it is now constituted.

McCosker and Dawson (1975) accept all putative canal crossers as crossers. For that reason they agree, although reluctantly it seems, with the conclusions of Bayer et al. (1970) that "there is no evidence to suggest any exchange of reef fishes through the present canal" and "current exchanges involve estuarine fishes, primarily gobies and fishes that can live among the fouling organisms on the hulls of ships." However, the collections by these workers were made so far out on the Continental Shelf that the collections shed no light on the question of migration across the isthmus; and if the conclusions are correct, they derive from the prescience of experienced biologists and not from any particular data presented. However, Hildebrand adduced information somewhat contrary to those conclusions.

Hildebrand (1937) previously gave evidence that the tarpon had crossed the isthmus and he gave more in 1939. He also said that *Anchovia parva* Meek and Hildebrand had crossed the freshwater barrier to the lower Miraflores Lock on the Pacific side. Remarkably enough he also reported the spotted jewfish, *Promicrops itaiara* (Lichtenstein), of the Atlantic from the lower Miraflores Lock. The fish weighed 47 pounds. These last two species are certainly putative crossers.

Significantly, Hildebrand's records and pictures show that several species and families of large fishes enter the locks, for example, the carangids or jacks, snooks, seabasses, groupers, snappers, grunts and sciaenids. These are not small blennies or gobies skulking in the fouling mats. Large fish can go through if they can pass the freshwater barrier. Gunter (1942) listed nine fishes from Panama that were fully euryhaline. On that list *Oostethus lineatus* was listed as only a "probable euryhaline." Meek and Hildebrand (1923) reported it as breeding in the fresh water of Gatún Lake.

In all, there are four fishes that have made indubitable crossings of the present Canal and gotten free of man's works. Only one, the tarpon, is a large fish. The other three are the pipefish *Oostethus lineatus*; a noneuryhaline goby, *Barbulifer ceuthoecus*, which evidently was carried by ship; and *Gobiosoma nudum*, the naked goby.

Additionally there are putatives, probables and possibles, numbering some 15 or so fishes, if circumtropical species are included, such as *Caranx hippos*, *Mugil cephalus* and *M. curema*. If such species do cross it would be difficult to prove unless they were tagged. This means that no effect of their crossing can be detected, even though they have been separated at least 5 million years and the Pacific jack was considered to be a different fish, *Caranx caninus*, until recently.

It is significant that both Hildebrand (1939) and McCosker and Dawson (1975) thought that they found evidences of hybridization in the gobies taken within the Canal.

The projected use of the Canal shows that in the year 2000 and thereabout the Canal traffic will use up in about a month's time the 22 billion cubic feet of water held in Gatún Lake as a reserve. Back pumping has been suggested as a way out of this dilemna and it will no doubt suffice. The objection has been raised that this action will increase the salinity to such an extent that it will cause Gatún Lake and the Canal to become a greatly used thoroughfare for the fishes and even the sea snakes from the Pacific side. The comments especially from various ichthyologists say that this action would be "unwise," "irresponsible," "indefensible," "dangerous," etc. Such terms are not science and in fact are those that can be heard in adversary court trials any day. One report has even suggested that there will be some sort of change in the germ plasm so that the invaders will exert some sort of overwhelming dominance over the indigenous biota. We may wonder on this basis what evolutionary horrors were caused by freeflowing and commingling oceans in the days before the isthmus became a complete barrier.

With regard to the salinity and what will happen when and if Gatún Lake attains a salinity of 5.0‰, which the engineers say is the most likely equilibrium to be attained by back pumping, there is not a great deal of information available. However, Gunter (1945) found that at the salinity range of between 0.0 and 5.0‰ in Texas waters, the number of species of fishes was about one-half of those recorded at salinities of 30.0‰ and above. Most of these were predominantly small and young specimens. Thus, Gatún Lake might be expected to assume characteristics of a very low-salinity estuary so far as the marine fishes are concerned. It would also retain a good bit of its freshwater fauna while losing some of it.

Myers (1949) was troubled about his category of Primary fishes because some of them have been found capable of tolerating high salinity, if acclimated gradually under experimental conditions. The salinity of a freshwater fish's blood is equal approximately to one-third sea water and at any salinity below 12.0‰ it maintains the hyperosmotic relationship of a freshwater fish to the salinity of the water. Some freshwater fishes live in quite highly saline lakes in the United States and hopefully the fishes of Gatún Lake would not be greatly disturbed by the slow increase of salinity to 5.0‰.

The efficiency of the Canal as a passageway for fishes between the oceans would be indubitably increased by back pumping. In terms of proportions of the salinity change, some 30 species of fishes would be expected to make the crossing. Presumably these would be the snooks, jacks, mullets, snappers, gobies and other fishes now known to be euryhaline and semi-euryhaline in this region. As a result, there would be a change in competition in habitat niches, in interbreeding, in food chains and some change in gene flow, population genetics and general competition.

In summary, the same old evolutionary panorama that goes on at all times in all oceans would be changed somewhat by back pumping, but not in any way that could be called unnatural. These changes would be hard to detect and hard to follow except for the presence of different species in an area where they were not known before. There is no reason to expect that these biological processes will fail to take place, or will change in any way to make them more or less strenuous, more or less wasteful of basic energy processes, or change in any way which can be objectively described as harmful, unless perhaps someone prefers one goby to another. Even so, these people can scarcely suffer over the preferred one's demise over a period of 500 to 1,000 years, which would probably be the time required. The same general situation will hold true for a sea level canal.

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